(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 June 2002 (20.06.2002)

PCT

(10) International Publication Number
WO 02/49009 A2

(51) International Patent Classification[7]: G11B

(21) International Application Number: PCT/IL01/01156

(22) International Filing Date:
12 December 2001 (12.12.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/254,539 12 December 2000 (12.12.2000) US

(71) Applicant *(for all designated States except US)*: **CONSELLATION TRID INC.** [US/US]; 805 Third Avenue 14th floor, New York, NY 10022 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **LEVICH, Eugene** [IL/IL]; 40/54, Yehuda Hanassi, 69393 Tel Aviv (IL). **MAGNITSKII, Sergei** [RU/RU]; 9-76 Garibaldi street, 117192 Moscow (RU). **KOZENKOV, Vladimir** [RU/RU]; 13-2-138, Likhachevskoe sh., 141700 Moscow region, Dolgoprudny (RU).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 02/49009 A2

(54) **Title:** PHOTOLITHOGRAPHIC METHOD FOR FABRICATING MICRO-RELIEF OPTICAL ORIGINAL DISCS, CARDS AND OTHER OPTICAL ELEMENTS AND MICRO-MINIATURIZED DEVICES

(57) **Abstract:** A contactless nondestructive method has been proposed for checking and adjusting the quality of spatial volumetric topology of the latent pattern image as a spatial pattern of information pits of optical disc original precursors or a pattern of precursors of micro-relief regions of various diffractive optical elements and micro-miniaturized original devices photolithographically generated in a photoresist layer and designated for subsequent fabrication of stampers thereof and further mass replication using injection moulding or photopolymerization. Said method includes illumination of the photoresist layer by polarized photochemically active radiation carrying information about the future spatial micro-structure of various micro-relief original products and reproduction of the spatial topology generated in the layer prior to the development of the exposed layer again using polarized but this time photochemically inactive radiation.

PHOTOLITHOGRAPHIC METHOD FOR FABRICATING MICRO-RELIEF OPTICAL ORIGINAL DISCS, CARDS AND OTHER OPTICAL ELEMENTS AND MICRO-MINIATURIZED DEVICES

BACKGROUND OF THE INVENTION

1. Field of the invention.

The present invention relates to a modified photolithographic technology for production of micro-relief optical original discs, for instance such as CD-ROM (Compact Disc – Read-Only Memory) or DVD-ROM (Digital Versatile Disc – Read-Only Memory) designed for mass replication of optical memory devices for audio-, video- and other information widely used at home and in industry.

More particularly, the invention relates to methods for checking writing modes and adjusting the quality of information recorded in real time on the original disc using the DRAW (Direct-Read-After-Write) procedure and/or optimization of development regimes for the exposed photoresist layer of the original disc through observation in the process or immediately thereafter of the latent image of information pit precursors formed in the layer.

In a broader sense, the present invention also relates to photolithographic production of generally diverse diffractive optical original elements and original micro-miniaturized devices with a relief microstructure that are further used to produce stampers therefrom and mass replication of said elements and microdevices by known methods such as injection compression moulding or photopolymerization "2P" process. In this case, the micro-relief pattern can be formed in the photoresist layer by both scanning by specified law of focused photochemically active radiation across the photoresist surface and contact or projection exposure of the photoresist layer via an appropriate photomask.

2. Description of the prior art

Micro-relief optical discs like CD ROM and DVD ROM, owing to their cheapness and simplicity have found wide application for mass replication of domestic audio- and videoinformation like pieces of music, films or TV programs for a large number of users.

In the CD- and DVD-ROM mass production technology, the process for fabricating a micro-relief original disc (OD) plays an important role determining the quality of reproducible video- and audio-information and economic aspects of the ROM production process [G. Bouwhuis et al., "Principles of Optical Disc Systems", Adam Hilger Ltd., Bristol and Boston].

Indeed, first original disc is produced as a glass substrate with a micro-relief (information pits) in the developed photoresist layer, then said OD is converted to a master disc by chemical or vacuum metallic coating with subsequent replication of said master disc through production of daughter metal copies (stampers) to be used for OD mass replication by means of injection compression moulding [P.E.J. Legierse, Trans. Inst. Met. Finish., 65 (1985), 13] or photopolymerization "2P' process [Haverkorn van Rijsewijk et al., Philips Tech. Rev., 40 (1982), 287; Kloosterboer et al., Philips Tech. Rev., 40 (1982), 298]. Therefore, the OD production process significantly defines the quality of the information reproduced from plastic copies and economic aspects of the entire production process at the initial stage of the process cycle.

Currently ODs are produced by photolithographic process using as a rule positive photoresists as a recording medium [P.L.M. Put et al., Proc. SPIE-Int. Soc. Opt. Eng., 1663 (1992), 38]. Said OD process is multistage. It involves cleaning of the glass substrate surface from dirt and application of an adhesion promoting layer followed by spin-coating of a photoresist layer subsequently exposed to unfocused, intensity-modulated laser beam carrying recorded information and development of the photoresist until microholes (information pits) appear in the exposed areas.

A thin layer of silver or nickel is then applied onto the OD micro-relief surface using wet chemical or vacuum procedure to generate a master disc with subsequent quality control of said master disc through reflection reading thereof. In case of positive control results, said master disc is used to produce stampers.

Thus, the quality control of information pits of the generated OD is performed upon completion of writing, development and metal coating thereof, i.e. after a master disc is produced. This prevents a possibility of active intruding in (adjustment of) the process of data writing and photoresist developing resulting in a potential significant reduction in the yield of good products and increasing the net cost thereof.

At the same time, the photolithographic process used in OD production is significantly different from the well-known process of optical microlithography applied for mass production of integrated circuits.

Firstly, to produce high-quality, low-size (0.4-0.6 μm wide) information pits, high-quality diffraction-limited optics with a numerical aperture of up to 0.8 is required. Said optics can ensure formation of the reading spot in the plane of the light-sensitive photoresist layer with a diameter of the order of 0.3-0.35 μm at half power against the power in the spot center. This necessitates precision of generation and adjustment of the recording laser beam.

Secondly, the photoresist layer exposure regimes considerably differ. In conventional microlithography, exposure as a rule is performed by continuous radiation sources with the exposure time of a few tenths of a second and radiation power density in the plane of the photosensitive layer of fractions or units of W/cm^2. In data writing on a rotating OD, the time of exposing one information element or pit does not exceed 100 ns while radiation power density measures units of MW/cm^2.

Thirdly, the photoresist layer thickness in OD (130-150 nm) is approximately of the order of magnitude less than that generally used in standard IC techniques. Rigid

allowances are imposed not only on the absolute size of the layer thickness but on spatial surface fluctuations of said thickness as well. Said thickness fluctuations along with deviations in exposure and development regime parameters can lead to deformations in the size of information pits generated in the photosensitive layer resulting in occurrence of noises at reading that distort the information signal. In real situations the signal-to-noise ratio is restricted by the surface roughness and deviations in geometrical size of nanometer-sized information pits [J.P.J. Heemskerk, Appl. Opt., **17** (1978), 2007].

The final spatial volumetric topology of microholes (pits) which is a criteria of the information quality of the process is strongly dependent of the exposing radiation dose [P.L.M. Put et al., Jpn. J. Appl. Phys., 36 (1997), 539]. Both deficiency and excess of said exposure is equally undesirable for generating a clear pit contour. Thus, exposure deficiency is manifested in irregularity of edges and remains of photoresist in exposed regions while exposure excess leads to larger pit size and destruction of the layer.

In this connection, of special interest is a possibility of thorough control and whenever possible adjustment of the topology of latent image of the future pit in the DRAW mode directly in the OD writing process prior to development or upon completion of writing before the development in order to optimize the photoresist development regimes. This can become possible through controlling the latent image of the future information pit formed in the photoresist layer by means of differentiating its physical and chemical properties in exposed and non-exposed regions. If the topology of the latent image of the pit meets the technical requirements, the photoresists layer continues to be illuminated, otherwise either the OD writing modes are adjusted or the writing process is stopped, the photoresist layer is removed from the substrate to be

re-coated and writing is done for the second time. In this way, the OD writing quality can be improved and ineffective loss of time and funds reduced.

It is known (Moreau W.M., "Semiconductor Lithography. Principles, Practices and Materials", Plenum Press. New York and London), that many photoresists have variable spectral properties (bleaching or darkening when illuminated). Thus, positive photoresists based on the novolac-o-naphthoquinone diazide photosystem subjected to illumination clear in the spectral range of activation. Increasing their transmittance can be used to check OD writing in real time scale. This method, however, is destructive as it leads to distortion or destruction of recorded pits the geometrical shape of which following the development significantly depends on the exposure power as discussed earlier.

A possible nondestructive method to control data recording can be an extra irradiation of the exposed OD by chemically inactive monochromatic X-ray or hard UV radiation with the wavelength ranging from decimal fractions to hundreds of Angstroms and registration of intensity of the secondary electron flux [U.S. Patent No 4,670,650 (1987)]. Said procedure is based on the electron (photoelectron) spectroscopy widely used in analytical chemistry for determining substance composition. Really, when positive photoresists based on photosensitive substances, for instance naphthoquinone diazides, are exposed to activating radiation with the wavelength less than 500 nm, there occurs photodestruction of the latter with the release of molecular nitrogen diffusing from the layer. Therefore, the latent image is formed as different concentrations of nitrogen atoms in exposed and non-exposed regions in the photoresist layer. The known method allows a contactless control of topology of the pattern generated in the photoresist layer but is difficult for practical realization as it requires application of high-resolution electron spectrometers.

In addition, said method is applicable only to the photolithographic technology using photoresists capable of changing their chemical composition, such as naphthoquinone-diazide-based photoresists. Said method is not applicable to photolithographic processes using for instance such negative photoresists as polyvinyl cinnamate and its derivatives which when irradiated manifest no variation in the chemical composition of the layer.

SUMMARY OF THE INVENTION

The present invention relates to a modified photolithographic technology for production of micro-relief optical original discs of for example CD- or DVD-ROM-type, as well as in a broader sense to a photolithographic technology for production of various micro-relief diffraction optical elements and micro-miniaturized instruments with a micro-relief microstructure used to obtain stampers therefrom and further mass replication of said optical elements by known techniques, such as compression moulding or photo polymerization.

The purpose of the invention is to develop a contactless nondestructive procedure for controlling and adjusting the quality of recorded information as a spatial volumetric topology of a latent image of OD information pit precursors or other micro-relief regions of diverse diffraction elements and micro-miniaturized devices formed in the photoresist layer as differences in optical properties manifested in exposed and non-exposed regions of the photoresist layer.

The aim is achieved by that in the proposed method including exposure of the photoresist layer to scanning across its surface by focused photochemically active radiation carrying recorded information and reading of the generated thereby latent image of precursors of information pits or micro-relief regions by means of irradiation of the disc surface by focused photochemically inactive radiation scanned synchronously with the recording radiation, exposure and reading are done by polarized radiation using at the final stage of an extra polarizer disposed between the OD or other product being generated and the photodetector recording the reading radiation incident on said photodetector.

At the stage of OD or other original product recording, in the photoresist layer immediately at the moment of exposure thereof by polarized photochemically active radiation a pattern of information pit or micro-relief microregions is generated as a latent anisotropic phase (birefringent) spatially modulated pattern on the isotropic background.

Further, the invention provides a bit-by-bit quality control of the recorded information directly in the process of photolithographic formation of the original product in real time scale by means of the DRAW technology used for WORM (Write-Once/Read-Many) optical disc writing.

Furthermore, the invention provides control and adjustment of the quality of recorded information through converting the latent phase, spatially modulated pattern by means of polarized photochemically inactive radiation into an amplitude, spatially intensity-modulated pattern using a polarizer-analyzer disposed between the generated original product and the photodetector.

Further, the subject of the invention is use of precisely measured parameters of latent phase pattern to ensure a feedback for adjusting the power of recording radiation, waveshaping thereof (pit exposure profiles) and the quality of focusing of the objective lens.

Further, the invention provides use of data obtained from quality control of recorded information, following computer processing, to optimize development regimes (selection of component composition for the developer, temperature and time of development, etc.) for the photoresist layer of the original product to produce a preset spatial volumetric profile for information pits of OD and other original microrelief products being formed.

Furthermore, the invention provides polarization writing of original products by means of contact or projection printing via a photomask.

Further, the subject of the invention is use of a CCD camera for a selection or total quality control of spatial topology of the latent image of the phase pattern of data recorded on the surface of original products upon completion of recording and prior to development of the photoresist layer.

Furthermore, the subject of the invention is use of data obtained from control of latent image topology using a CCD camera to optimize the photoresist layer development regime.

Further, the subject of the invention is use as photoresists of positive photoresists from the naphthoquinone diazide classes, negative photoresists from the class of polyvinyl cinnamate and derivatives thereof, azides like 2,6-bis(4-azidobenzilidene)-4-methylcyclohexanone and derivatives thereof, and negative inorganic photoresists like amorphous chalcogenide semiconductors of As_2Se_3.

Further, the invention provides doping said organic photoresists with special photosensitive substances, for instance azo dyes, absorbing in the photosensitivity range of photoresists and manifesting an effect of photoinduced birefringence under the action of activating radiation.

For a fuller understanding of the above-mentioned and other aspects of the present invention, reference should be made to the following detailed description and examples taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is schematic view illustrating production of a master disc using a prior art (a) process and the proposed (b) technology.

Fig. 2 is an absorption spectrum of the FP-383 positive photoresist prior (Curve 1) and following (Curves 2 and 3) radiation by polarized light (405 nm).

Fig. 3 is kinetics of bleaching (T) of the FP-383 photoresist layer at 405 nm following polarized light radiation at the same wavelength (Curve 1) and respective induction of birefringence (Δn) in the transparence region at 632.8 nm (Curve 2), and depth of etching (Δd) of the developed photoresist layer as a function of exposure energy (Curve 3).

Fig. 4 is birefringence induction kinetics in polyvinyl cinnamate derivative films (Curve 1) and amorphous chalcogenide semiconductor As_2Se_3 (Curve 2).

Fig. 5 is a cross-sectional view of the exposed to polarized radiation OD with a photoresist.

Fig. 6 is a photograph of a latent polarization image generated in the photoresist layer.

Fig. 7 is an embodiment of the device for data writing on a micro-relief OD in real time.

Fig. 8 is an embodiment of the device for OD writing quality control enabling checking spatial topology of the latent image of precursors of written information pits prior to the OD development.

Fig. 9 is a schematic representation of the correlation between one-dimensional spatial profile of exposure energy distribution at writing of an information pit in the photoresist layer (A), profile of latent anisotropic image of the information pit precursor (B), profile of spatial concentration distribution for products of photochemical reaction (C) following exposure and one-dimensional geometric profile of respective developed information pit (D).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows process stages for fabricating a master disk using the prior-art (a) and the proposed (b) technologies. It can be seen that the known process utilizing a photoresist as a recording medium to check the quality of information written on an OD demands preliminary development and metallic coating of the photoresist layer after completing data writing thereon. It allows no adjustment of the writing quality of the information pit immediately in the writing process or quality control of the filly

exposed (written) OD prior to development thereof in order to optimize the regimes of the latter. In compliance with the proposed technology, non-destructive control of the latent image of information pit precursors is possible directly in the process of data writing on the OD enabling an active intervention in the writing process and correction thereof. In addition, a partial or complete computer analysis of the latent image quality of future information pits in order to optimize development regimes of the recorded OD.

Figs. 2-8 explain practicability of said process.

In the present invention, it has been established that under the action of polarized or even non-polarized but directed radiation most of positive and negative photoresists used in photolithography and in particularly in OD production show an effect of photoinduced optical anisotropy (absorption and birefringence dichroism). The amount of anisotropy induced in the layer depends on the exposure energy while the direction of the optical axis is determined by the direction of the polarization vector of activating radiation (as a rule, perpendicular to the polarization vector) or propagation direction thereof for non-polarized radiation.

Said effect was observed in positive photoresists based on naphthoquinone diazide as well as in negative ones based on polyvinyl cinnamate and derivatives thereof, azides of the type of 2,6-bis(4-azidobenzylidene)-4-methylcyclohexanone and derivatives thereof, and in inorganic negative photoresists based on amorphous chalcogenide semiconductors like As_2Se_3.

To enhance induced birefringence at exposure in the process of data recording in layers of organic photoresists, special photosensitive anisotropic substances , for instance azo dyes, absorbing in the range of said organic photoresists and manifesting the effect of photoinduced anisotropy can be added thereto.

Induced anisotropy emerges directly in the process of irradiation, as of photochemical reactions in similar layers proceed for not more than hundredth fractions of a microsecond, and maintains for as long as several hours or even years. Birefringence (BR) occurring in the exposed layers is induced in the region of their transparence, i.e. outside the spectral range of photosensitivity.

All the above allows a non-destructive control of information recorded in the photoresist layers by photochemically inactive radiation, for instance by a He-Ne

(632.8 nm) or semiconductor (of the order of 700 nm) laser in real time or upon completion of data recording prior to the development of the photoresist layer.

At the stage of OD writing by polarized photochemically active radiation, precursors of future (after the development) information pits are formed in the photoresist layer as a latent anisotropic phase (birefringent) spatially modulated pattern on the isotropic background.

OD recording quality control is performed by means of photochemically inactive polarized radiation through converting the latent phase image of information pit precursors to an amplitude pattern using a polarizer-analyzer disposed between the OD and the photodetector.

Spatial intensity distribution of the reading radiation (I(x,y)) transmitted through the latent image of the information pit precursor and the analyzer is defined by the magnitude of BR induced in the process of writing:

$$I(x,y) = I_0 \times \mathrm{Sin}^2\{\pi\Delta n(x,y)d/\lambda\} = \mathrm{Const} \times (\Delta n(x,y))^2, \qquad (1)$$

where

$\Delta n(x,y)=\Psi(H(x,y))$ is spatial distribution of BR induced in the information pit precursor under the action of activating radiation with energy H(x,y);

d is the photoresist layer thickness;

λ is the reading radiation wavelength;

I_0 is intensity of reading radiation incident on the OD;

$\mathrm{Const} = I_0 \times (\pi d/\lambda)^2$ and

X ,Y are space coordinates in the plane of the photoresist layer.

It is assumed that the optical axes of the polarizer and the analyzer are orthogonal, while the optical axis of the BR induced in the photoresist layer is at an angle of 45° relative to said axes.

Expression (1) considers that due to the small thickness (130-150 nm) of the photoresist layer, absorption at the activating radiation wavelength therein is low, its

intensity throughout the layer thickness Z and hence BR are uniform and the magnitude of the phase delay (φ) is low ($\varphi = 2\pi\Delta n(x,y)d/\lambda$).

In Fig. 2 an absorption spectrum is given for a positive photoresist based on naphthoquinone diazide and phenol-formaldehyde resin (Russian NIOPIK company's trade mark FP-383) prior (Curve 1) and following (Curves 2 and 3) irradiation by polarized radiation (405 nm). Prior to the irradiation the photoresist layer was fully isotropic in terms of its optical properties and showed neither absorption dichroism nor birefringence. As a result of polarized radiation with the energy of the order of 120 mJ/cm^2 and photochemical reaction the layer became anisotropic. This was manifested in inducing dichroism in the absorption band (Fig. 2, Curves 2 and 3) and birefringence (Fig. 3, Curve 2) in the region of transparence of the photoresist layer.

Consequently, local irradiation of the photoresist layer by polarized photochemically active radiation may lead to generation of a latent image of information pit precursors as surface-modulated absorption dichroism and birefringence (Δn), their magnitudes being dependent on the exposure energy dose (Fig. 2, Curves 2 and 3; Fig. 3, Curve 2). Figure 3 also shows a kinetic curve of the photoresist layer transmission (T) variation during irradiation at the activation wavelength (Curve 2) unambiguously characterizing the kinetic process of accumulation of products of photochemical reaction (Nfp) and the function of the depth of etching in the layer (Δd) (Curve 3) measured for certain regimes of layer formation, exposure and development. It can be seen from Fig. 3 that there exist certain correlations between the BR induced in the exposed photoresist layer and the layer etching depth for specified exposure energies. Said correlations vary depending on the composition and regimes of preparation, exposure and development of the photoresist layer and still are unambiguously correlated with each other. The unambiguous nature of the correlation among Nfp, Δn and Δd is dictated by the fact that to develop a relief image in the photoresist layer it is requisite to photodecompose only about half of naphthoquinone diazide molecules contained therein (Moreau W. M., "Semiconductor Lithography. Principles, Practices, and Materials", Plenum Press. New York and London).

Fig. 9 schematically illustrates correlation between a one-dimensional spatial profile of exposure energy distribution H(x) of information pits normalized to the exposure level in the center of laser writing spot (A), profile of the latent anisotropic image of the information pit precursor as induced in the layer BR Δn (x) (B) and profile of spatial concentration distribution for products of the photochemical reaction Nfp (x) formed under the action of said writing spot (C). Bid there is a one-dimensional profile Δd (x) of the corresponding developed information pit (D).

Depending on the above-mentioned conditions, quantitative correlations between said profiles may differ but they always remain unambiguous. Consequently, through controlling the spatial profile of the latent anisotropic image $\Delta n(x) = \Psi(H(x))$ of information pit precursors, it is possible to control and adjust the quality of the geometric profile of recorded information pits $\Delta d(x)$ both in real time and while developing the photoresist layers.

Identical dependences have been established for negative photoresists based on polyvinyl cinnamate and derivatives thereof, amorphous chalcogenide semiconductors (Fig. 4, Curves 1 and 2) and photosensitive layers based on azides.

Fig. 5 provides a cross-sectional view of an OD with a photoresist layer exposed to polarized activating radiation. Arrow 1 indicates direction of the optical axis in the exposed and nondeveloped area (information pit precursor) 2 of the photoresist layer 3 on the glass substrate 4, while isotropic, nonexposed areas 5 are shown by crossing arrows 6.

Fig. 6 exemplifies a photograph of the latent polarized image of the transparency written by polarized photochemically active radiation (the wavelength is less than 450 nm) on the FP-383 positive photoresist and visualized via the analyzer by polarized photochemically inactive visible radiation (the wavelength is more than 550 nm).

Figs. 7 and 8 represent a schematic illustration of two possible embodiments of the system for micro-relief OD recording on a photoresist using the proposed method for control and adjustment of the quality of information pits.

The embodiment presented in Fig. 7 enables control and adjustment of the bit-by-bit writing mode by means of DRAW data retrieval in real time scale. During writing, modulator 13 modulates the polarized by polarizer 12 laser beam 11 by means of information signal 14. Modulated writing beam 15 is focused by objective lens 16 on the photoresist layer 17 applied onto the surface of a glass disk 18 rotating at a certain speed. As shown earlier, there occurs an anisotropic photochemical reaction in the photoresist layer and in the exposed microregion precursors of information pits are generated as a birefringent space-modulated pattern against the isotropic background. The BR size and spatial distribution in information pit

precursors (spatial topology of information pit precursors) are determined by the magnitude and spatial distribution of the recording pulse energy. (Dependence of the BR size on exposure energy is illustrated in Figs. 3 and 4.) The latter is determined by the appropriate modulation code 14 and the quality of the focusing optics 16.

The latent image of these phase information pit precursors is read bit by bit, in real time scale by focused photochemically inactive laser radiation 19 (for instance, from a He-Ne laser 20 with the wavelength of 632.8 nm). To this end, the reading beam 19 is converted by means of polarizer 21 to a linearly polarized beam 22 and passing through a dichroic mirror 23 is focused by means of the objective lens 16 in the focusing area of the writing beam 15 on the photoresist layer 17. Having passed through the OD micro-region with the latent anisotropic image of information pit precursor recorded therein, the linearly polarized reading beam 22 converts to an elliptically polarized beam 24 that partly passes through the analyzer 25. The objective lens 26 projects the visualized image of the information pit precursor onto the photoelectric detector 27.

The detected playback signal 28 provides real-time information of critical mastering parameters, such as, HF amplitudes, asymmetry, and after decoding, digital error rate. The real-time information is used to create a closed-loop feedback system, such that appropriate record power laser 29 and pit exposure profiles (objective lens 16) are used during the mastering process.

Thus, the proposed method for precision measurement of real-time latent image parameters of information pit precursors allows a feedback by means of

adjustment the power of recording radiation, waveshaping thereof (pit exposure profiles) and the quality of focusing of the objective lens 16.

Following computer processing, the OD writing quality control data can be also used to optimize OD development regimes (developer composition, temperature, time of development, etc.). This is possible because at development kinetics of accumulation of products of the photochemical reaction and the size of BR induced in the photoresist layer, as well as the etching depth thereof are unambiguously dependent on the exposure energy for preset parameters of exposure (relative ambient humidity, power density of the activating radiation, etc.) and development regimes (Fig. 9).

Fig. 8 illustrates another embodiment of the proposed method wherein a CCD camera 30 is used as a photodetector 27. In this case, a possibility is provided for a selection or, if necessary, total control of the spatial topology quality of latent images of information pit precursors on the surface of OD 31 upon completion of writing thereof. The scheme of retrieval illustrated in Fig. 8 is identical to the one given in Fig. 7 and also comprises a polarizer 21 and analyzer 25 while the objective lens 16 simultaneously reads a few thousand latent images of information pit precursors which by means of objective lens 26 are projected in the plane of the CCD camera 30. If necessary, the entire surface of the OD 31 can be controlled in this way. Said possibility of analysis of 28 latent images of information pit precursors prior to the development enables optimization of OD development conditions (developer composition, temperature, time of development, etc.) after recording with taking into consideration of, for instance, regimes of baking of the photoresist layer prior to exposure, averaged exposure radiation intensity data, spatial radiation distribution (topology) in the focused exposure spot and corresponding size and spatial distribution (topology) of birefringence in precursors of information pits.

As mentioned in the Field of the Invention, more generally the present invention relates to photolithographic production of diverse diffractive optical original elements and micro-miniaturized original devices with a micro-relief structure applied for fabricating stampers therefrom and further replication of said elements and micro-devices using known methods, for instance injection compression moulding. In this case, the micro-relief pattern can be formed in the photoresist layer by either scanning

by specified law of photochemically active radiation focused across the photoresist surface and contact or projection exposure of the photoresist layer via an appropriate photomask.

Diffractive optical elements, originals of which can be fabricated by the method proposed in this invention, are in particular exemplified by kinoforms, synthetic surface relief holograms, phase gratings and binary optics that replace or improve conventional optical components in various application fields, such as projection LC displays in military aircraft, optical storage devices, optoelectronic modules for data communications, laser systems, ophthalmic products for the vision impaired, et al.

Micro-miniaturized devices with a relief microstructure, originals of which can be also fabricated by the proposed method, are exemplified by microcuvettes used in pharmaceutical industry for drug formulation and testing.

Quality control or even adjustment for the latent image of said elements or microdevices could be realized either in real time as illustrated, for instance in Fig. 7, or upon completing the process of exposure using a CCD camera, as illustrated in Fig. 8.

Thus, the proposed invention allows one to obtain in advance statistical data on correlation between the geometric size and spatial profile of latent pattern images generated in the photoresist layer, the geometric size and spatial profile of the relief patterns obtained after the development of the photoresist layer and development conditions thereof. This invention enables automatic control of the photolithographic process through establishing a dynamic connection between the precision control of photoresist application, annealing, exposure and development regimes. This ensures proper size of the products formed, fast readjustment of photolithographic equipment to produce another product, higher yield of effective products and reduction of prices thereof at the expense of reduced material consumption and production time.

It should be understood that the present invention is not limited to the specific embodiments described in this specification and admits diverse modifications, such as specific fields of application, schematic arrangement of polarizers and other elements used to control and adjust the latent image generated in the photoresist layer, the composition and class of the photoresist proper, covered by the appended claims.

WHAT IS CLAIMED IS

1. A method of optical control of quality of at least one of geometric shape and spatial volumetric topology of the latent pattern as a spatial pattern of information pit precursors of original information optical carrier photolithographically generated in a photoresist layer by illuminating the photoresist layer by photochemically active radiation, the method comprising the steps of:
   i. illuminating said latent pattern by photochemically inactive reading radiation,
   ii. measuring light response caused by said latent pattern,
   iii. analyzing said measured data and determining at least one of geometric shape and spatial volumetric topology of the latent pattern by differences in optical properties between the exposed and non-exposed regions.
2. The method according to Claim1, wherein the latent pattern is formed in the photoresist layer by means of nonpolarized photochemically active radiation as a polarization phase space-modulated pattern on the isotropic background.
3. The method according to Claims 1,wherein the step or illuminating said latent pattern by photochemically inactive reading radiation is carried out by scanning of the focused radiation across the photoresist layer surface substantially synchronously with the photochemically active radiation.
4. The method according to Claim 1, wherein said analyzed measured data is further used as a feedback signal for adjusting at least one of the parameters of photochemically active radiation of recording mode through adjusting the power of the recording radiation, waveshaping thereof (pit exposure profiles) and the quality of focusing of the objective lens.
5. The method according to Claim 3, wherein said analyzed measured data is further used as a feedback signal for adjusting at least one parameter of photochemically active radiation.

6. The method according to claim 4, wherein said adjusted parameter of photochemically active radiation recording mode are at least one of power, waveshaping and focus.

7. The method according to claim 5, wherein said adjusted parameter of photochemically active radiation recording mode are at least one of power, waveshaping and focus.

8. The method according to Claim 1, and also comprising the step of using said analyzed measured data as a feedback signal for further adjusting development regimes of the exposed photoresist layer.

9. The method according to Claim 4, and also comprising the step of using said analyzed measured data as a feedback signal for further adjusting development regimes of the exposed photoresist layer.

10. The method according to Claim 1, wherein the step of measuring light response s performed by applying CCD camera upon completing the exposure and prior to the development.

11. The method according to Claim 10, wherein said measuring is applied to at least one selected area of said latent pattern.

12. The method according to Claim 10, wherein said measuring is applied to entire latent pattern.

13. The method according to Claim 10, and also comprising the step of using said analyzed measured data as a feedback signal for further adjusting development regime of the exposed photoresist layer.

14. The method according to Claim 1, wherein said original information optical carrier is an optical disc.

15. The method according to Claim 3, wherein said original information optical carrier is an optical disc.

16. The method according to Claim 1, wherein said original information optical carrier is an optical card.

17. The method according to Claim 3, wherein said original information optical carrier is an optical card.

18. A method of photolithography for manufacturing a spatial pattern of information pit precursors of original information optical carrier, the method comprising the steps of:

   i. generating spatial pattern of information pit in a photoresist layer by illuminating the photoresist layer by photochemically active radiation;

   ii. illuminating said latent pattern by photochemically inactive reading radiation,

   iii. measuring light response caused by said latent pattern,

   iv. analyzing said measured data and determining at least one of geometric shape and spatial volumetric topology of the latent pattern by differences in optical properties between the exposed and non-exposed regions.

   v. adjusting at least one parameter of photochemically active radiation in accordance with determined at least one of geometric shape and spatial volumetric topology of the latent pattern.

19. The method according to Claims 18,wherein the step or illuminating said latent pattern by photochemically inactive reading radiation is carried out by scanning of the focused radiation across the photoresist layer surface substantially synchronously with the photochemically active radiation.

20. The method according to Claim 18, wherein said adjusted parameter of photochemically active radiation of recording mode is at least one of power, waveshaping and focus.

21. The method according to claim 19, wherein said adjusted parameter of photochemically active radiation recording mode is at least one of power, waveshaping and focus.

22. The method according to Claim 18, and also comprising the step of using said analyzed measured data as a feedback signal for further adjusting development regimes of the exposed photoresist layer.

23. The method according to Claim 19, and also comprising the step of using said analyzed measured data as a feedback signal for further adjusting development regimes of the exposed photoresist layer.

24. The method according to Claim 18, wherein the step of measuring light response is performed by applying CCD camera upon completing the exposure and prior to the development.

25. The method according to Claim 24, wherein said measuring is applied to at least one selected area of said latent pattern.

26. The method according to Claim 25, wherein said measuring is applied to entire latent pattern.

27. The method according to Claim 25, and also comprising the step of using said analyzed measured data as a feedback signal for further adjusting development regimes of the exposed photoresist layer.

28. The method according to Claim 18, wherein said original information optical carrier is an optical disc.

29. The method according to Claim 19, wherein said original information optical carrier is an optical disc.

30. The method according to Claim 18, wherein said original information optical carrier is an optical card.

31. The method according to Claim 19, wherein said original information optical carrier is an optical card.

32. The method according to Claim 18, where positive photoresists are used as photoresists.

33. The method according to Claim 32, where photoresists from the class of naphthoquinone diazide novolacs are used as positive photoresists.

34. The method according to Claim 18, where negative photoresists are used as photoresists.

35. The method according to Claim 34, where negative photoresists from the class of polyvinyl cinnamates are used as negative photoresists.

36. The method according to Claim 34, where azide-containing photoresists of the 2,6-bis(4-azidobenzylidene)-4-methylcyclohexanone type are used as negative photoresists.

37. The method according to Claim 34, where amorphous chalcogenide semiconductors are used as photoresists.

38. The method according to Claim 37, where As_2Se_3 is used as amorphous chalcogenide semiconductor.

39. The method according to Claim 18, where special photosensitive anisotropic substances, for instance azo dyes, absorbing in the range of spectral photosensitivity of organic photoresists and manifesting the effect of photoinduced birefringence under the action of polarized activating radiation are added to said organic photoresists.

40. The method according to Claim 19, where special photosensitive anisotropic substances, for instance azo dyes, absorbing in the range of spectral photosensitivity of organic photoresists and manifesting the effect of photoinduced birefringence under the action of polarized activating radiation are added to said organic photoresists.

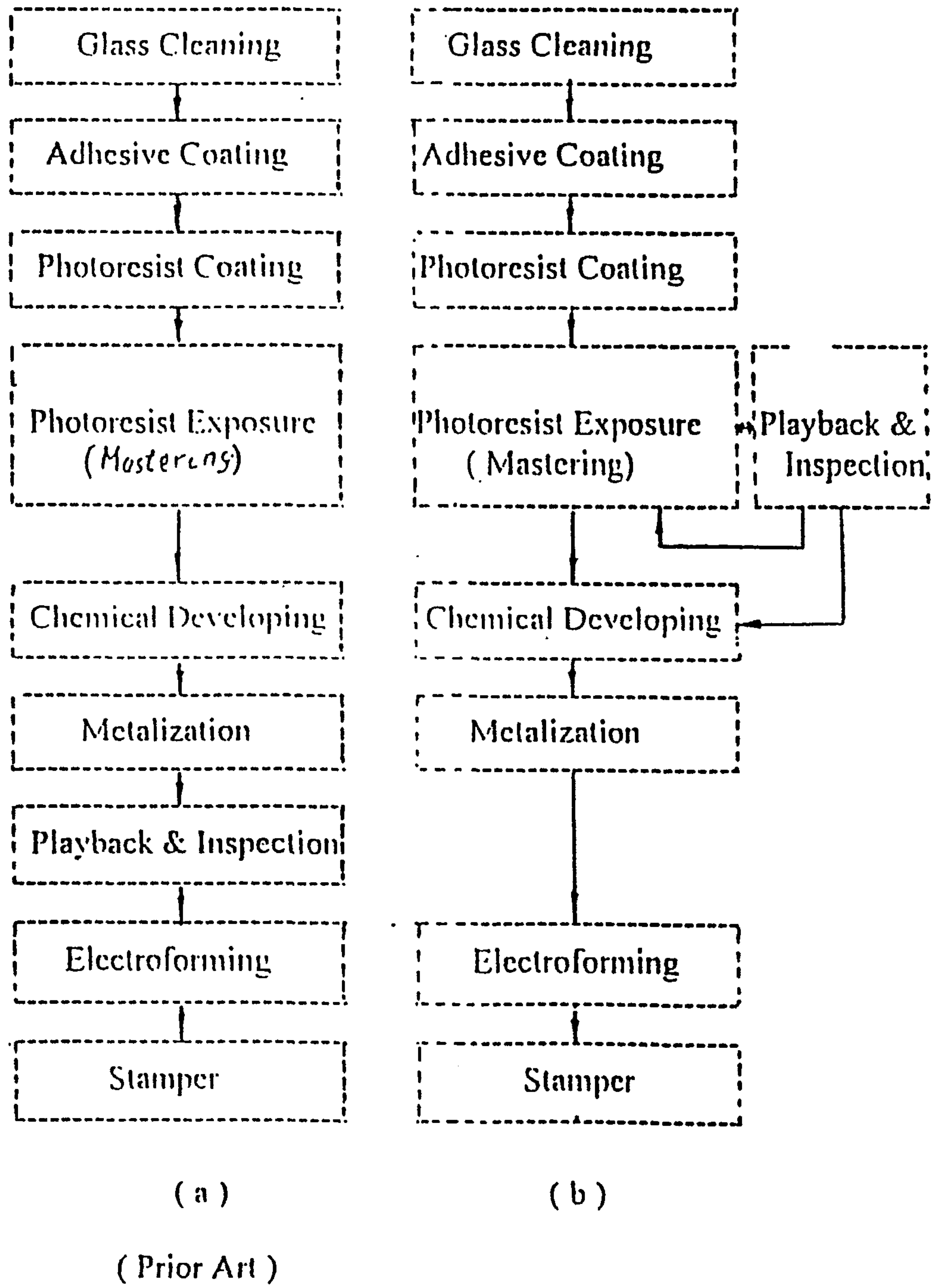
Glass Cleaning
Adhesive Coating
Photoresist Coating
Photoresist Exposure (Mastering)
Chemical Developing
Metalization
Playback & Inspection
Electroforming
Stamper
Glass Cleaning
Adhesive Coating
Photoresist Coating
Photoresist Exposure (Mastering)
Playback & Inspection
Chemical Developing
Metalization
Electroforming
Stamper
(a)
(b)
(Prior Art)

FIG. 1

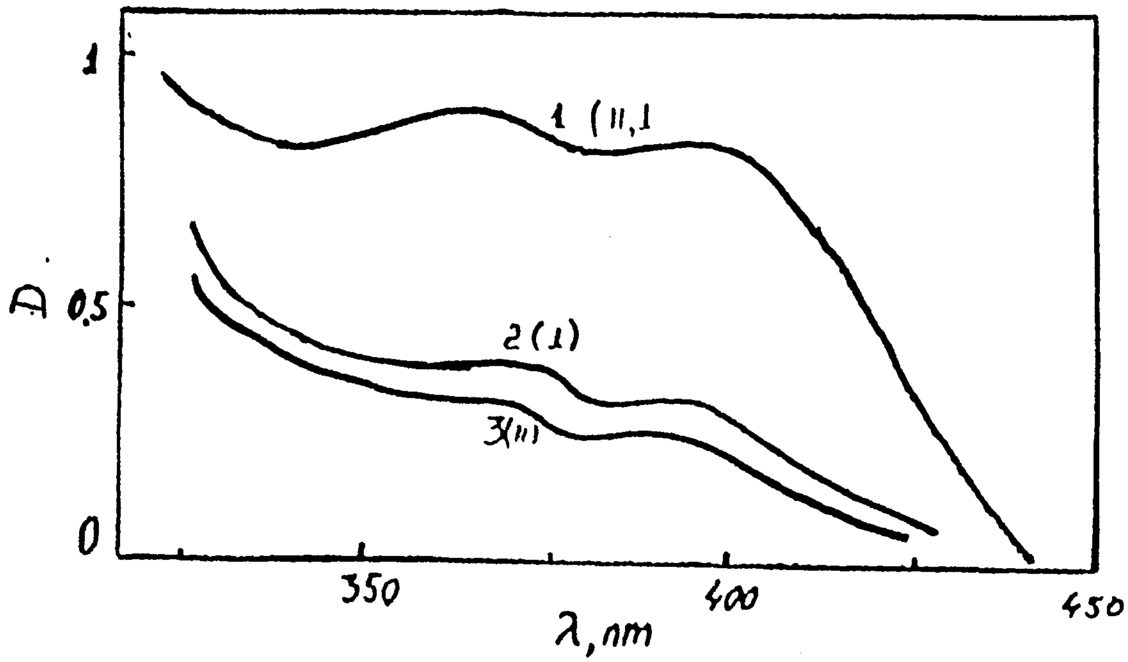
1
D 0.5
0
1 (II, I
2 (I)
3(II)
350
400
450
λ, nm

FIG. 2

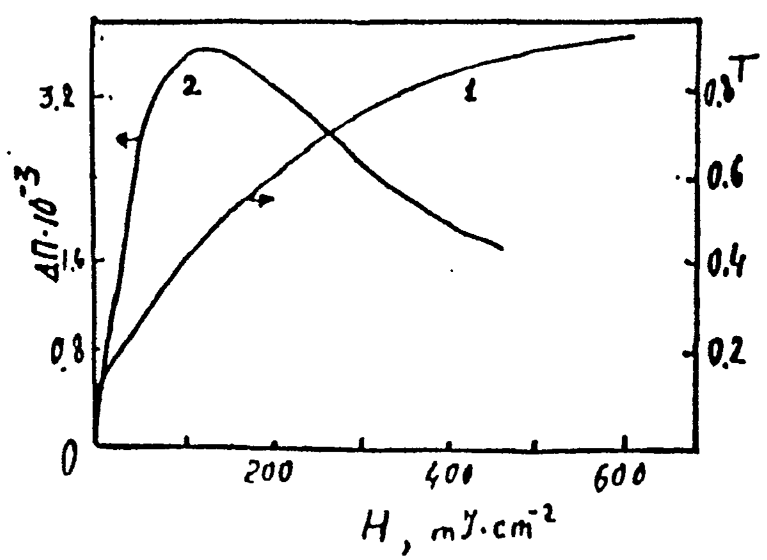
3.2
1.6
0.8
0
2
1
0.8
0.6
0.4
0.2
T
200
400
600
H, mJ·cm⁻²

FIG. 3

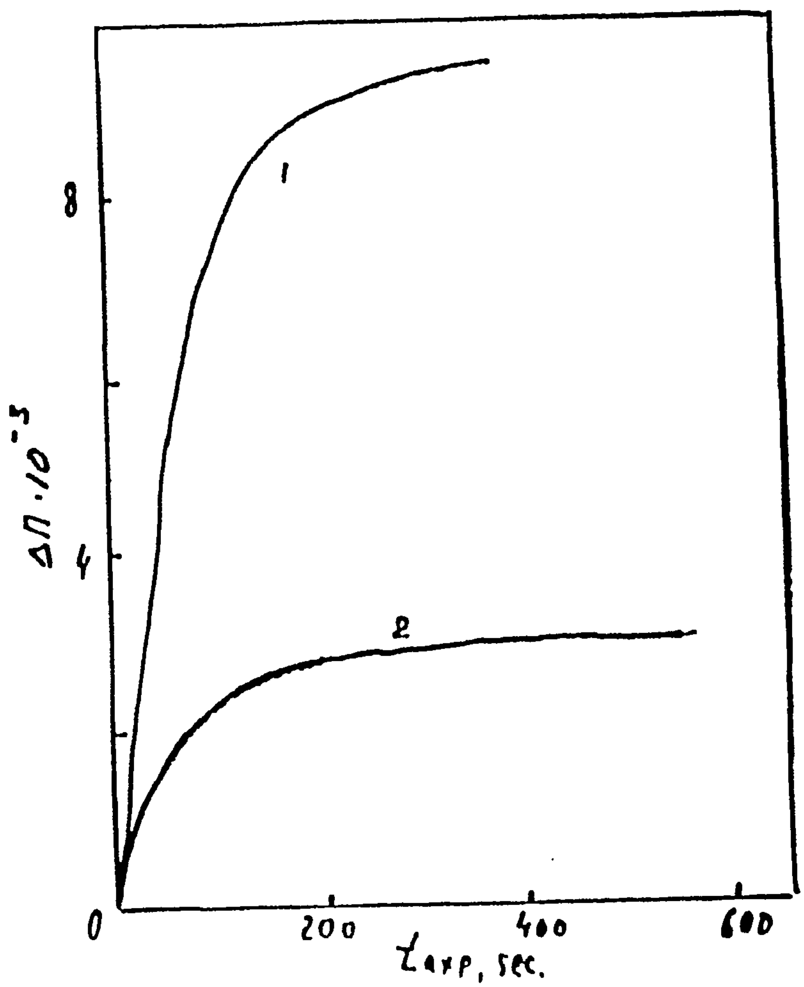

FIG. 4

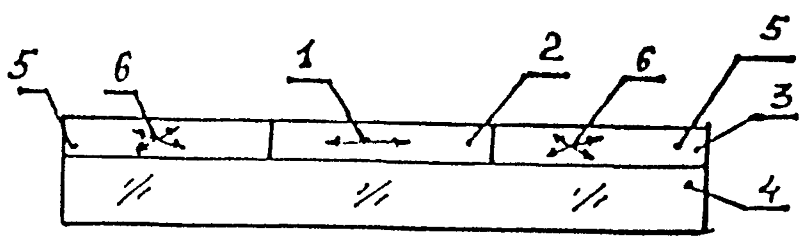

FIG. 5

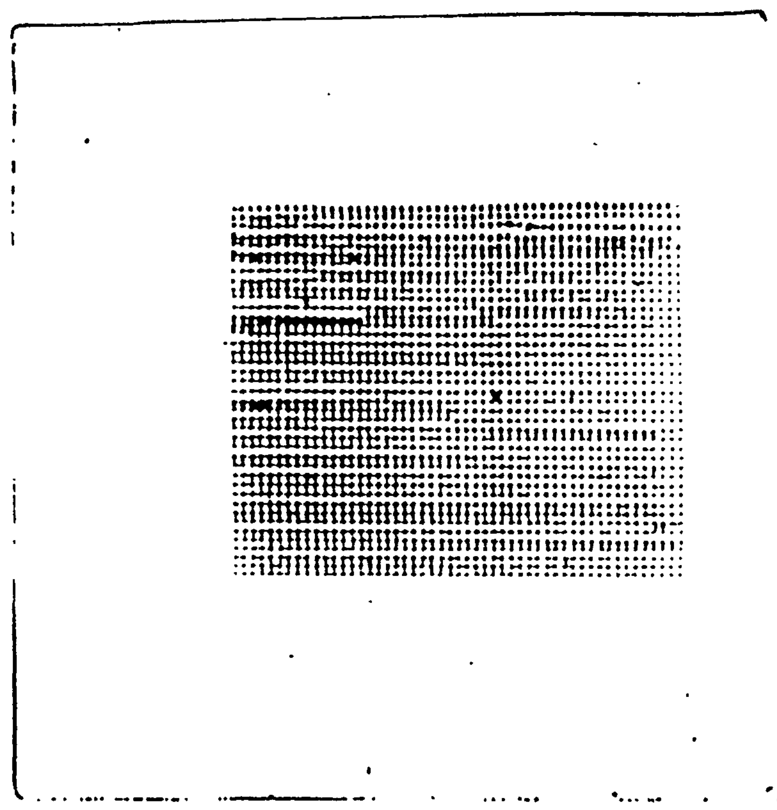

FIG. 6

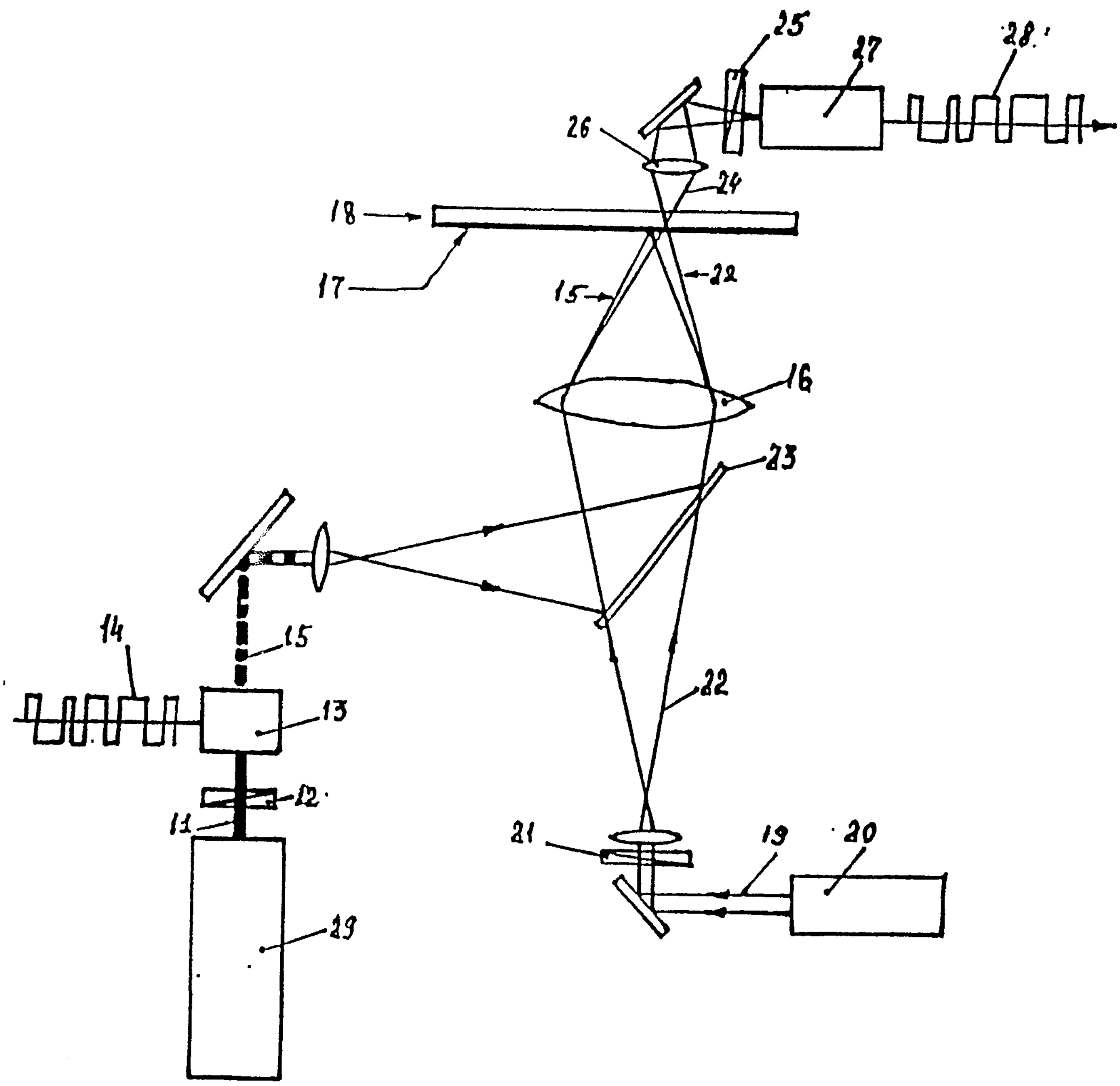

FIG. 7

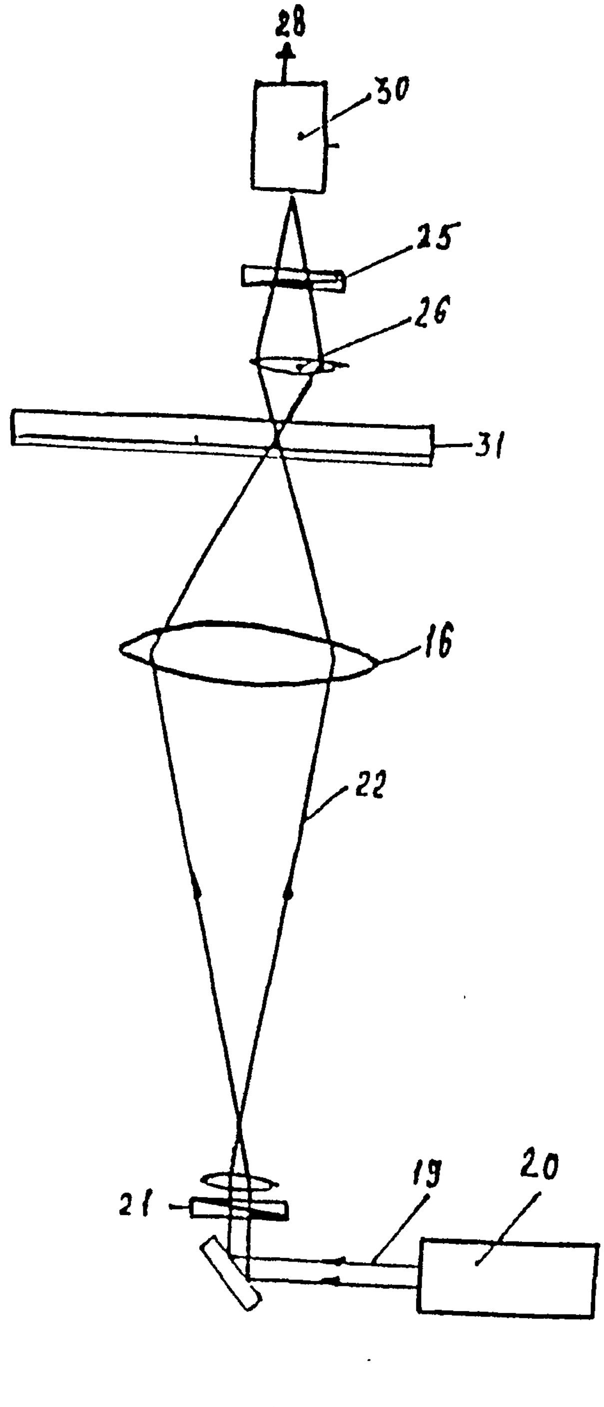

FIG. 8

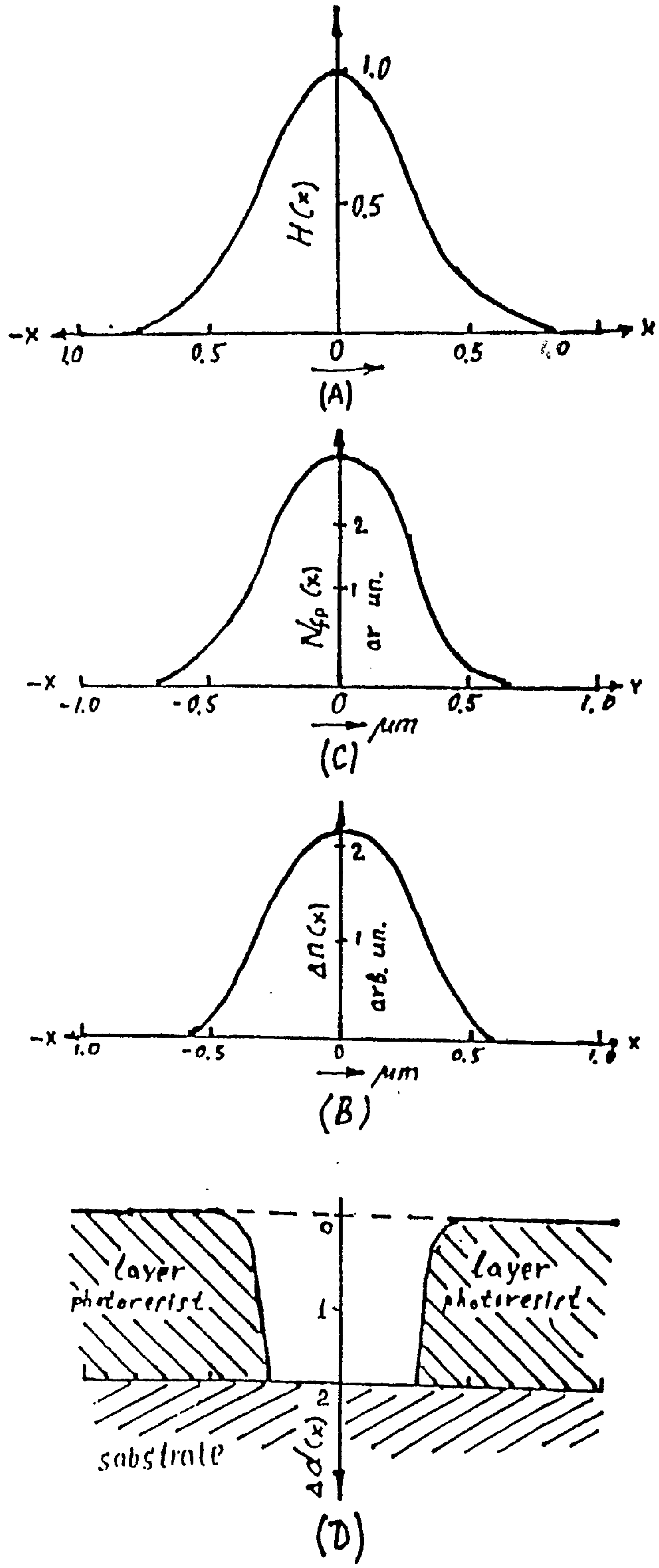
1,0
0.5
H(x)
-X
X
1.0
0.5
0
0.5
1.0
(A)
2
1
$N_{fp}(x)$
ar un.
-X
Y
-1.0
-0.5
0
0.5
1.0
μm
(C)
2
1
Δn(x)
arb. un.
-X
X
1.0
-0.5
0
0.5
1.0
μm
(B)
0
1
2
layer
photoresist
layer
photoresist
substrate
Δd(x)
(D)

FIG. 9